TRANSMITTAL OF APPEAL BRIEF (Large Entity)

Docket No.
50041-00037

In Re Application Of:
XUE, et al.

Application No.	Filing Date	Examiner	Customer No.	Group Art Unit	Confirmation No.
09/591,437	June 9, 2000	Thoi V. Duong	25231	2871	3249

Invention: CHEVRON-FREE FLC DEVICE

COMMISSIONER FOR PATENTS:

Transmitted herewith is the Appeal Brief in this application, with respect to the Notice of Appeal filed on:

The fee for filing this Appeal Brief is: **$500.00**

☒ A check in the amount of the fee is enclosed.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☒ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. 50-1419. I have enclosed a duplicate copy of this sheet.

☐ Payment by credit card. Form PTO-2038 is attached.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

Signature

Dated: March 7, 2006

ROBERT G. CROUCH
REGISTRATION NO. 34,806
MARSH FISCHMANN & BREYFOGLE
3151 S. VAUGHN WAY, SUITE 411
AURORA, COLORADO 80014
720-562-5506

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450" [37 CFR 1.8(a)] on

March 7, 2006.
(Date)

Signature of Person Mailing Correspondence

Maureen Sileo

Typed or Printed Name of Person Mailing Correspondence

cc:

P30LARGE/REV07

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re the Application of:	Group Art Unit: 2871
JUIZHI XUE, et al.	Examiner: Thoi V. Duong
Serial No.: 09/591,437	
Filed: June 9, 2000	
Confirmation No. 3249	
Atty. File No.: 50041-00037	
For: "CHEVRON-FREE FLC DEVICE"	

CERTIFICATE OF MAILING

I HEREBY CERTIFY THAT THE ORIGINAL AND TWO COPIES OF THIS CORRESPONDENCE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE AS FIRST CLASS MAIL IN AN ENVELOPE ADDRESSED TO COMMISSIONER FOR PATENTS, MAIL STOP: APPEAL BRIEF-PATENTS, P.O. BOX 1450, ALEXANDRIA, VA 22313-1450 ON MARCH 7, 2006

MARSH FISCHMANN & BREYFOGLE LLP

BY: Maureen Sileo
MAUREEN SILEO

APPELLANTS' BRIEF ON APPEAL

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450
MAIL STOP: APPEAL BRIEF - PATENTS

Dear Sir:

The structure of Appellant's Brief is as follows and in the order required by 37 CFR § 41.37:

I. Real Party in Interest
II. Related Appeals and Interferences
III. Status of Claims
IV. Status of Amendments
V. Summary of Claimed Subject Matter
VI. Grounds of Rejection to be Reviewed on Appeal
VII. Argument
VIII. Claims Appendix

03/14/2006 DEMMANU1 00000036 09591437
01 FC:1402 500.00 OP

Appendices

A. Claims involved in the Appeal.

B. A copy of U.S. Patent No. 6,141,076 to Liu et al.

C. A copy of passages from Ferroelectric and Antiferroelectric Liquid Crystals, by Sven T. Lagerwall (1999).

D. A paper by Noel A. Clark and Sven T. Lagerwall entitled "Surface-Stabilized Ferroelectric Liquid Crystal Electro-optics: New Multistate Structures and Devices," published in Ferroelectrics vol. 59, pp. 25-67 (1984).

E. A page from a chapter entitled "Electric Field Effects in Liquid Crystals," by L.M. Blinov in the *Handbook of Liquid Crystal Research* edited by Peter J. Collings and Jay S. Patel (Oxford University Press, Oxford, 1997).

F. Data sheet from Chisso Petrochemical Corp., dated March 27, 1989.

I. REAL PARTY IN INTEREST

The inventor of the above-noted patent application has assigned all respective rights in relation to the above-noted patent application, including any resulting patent, to Displaytech, Inc. a Delaware corporation with a place of business in Longmont, Colorado, in the Assignment that was recorded at the U.S. Patent Office ("PTO") on September 25, 2000 at Reel 011107, Frame 0500. Therefore, Displaytech, Inc. is the real party in interest in this appeal.

II. RELATED APPEALS AND INTERFERENCES

Appellant, Appellant's legal representative, the assignee of the above-noted patent application, and the named inventors for the above-noted patent application are all unaware of any appeal(s) or interference(s) which will directly affect, be directly affected by, or have a bearing on the Board's decision in the pending appeal.

III. STATUS OF CLAIMS

The status of the claims is as follows:

1. Claims pending: 1 - 26;
2. Claims rejected: 1 - 10, 12, and 14-26;
3. Claims objected to: 11
4. Claims allowed: 13; and
5. Claims appealed: 1 - 12 and 14-26.

IV. STATUS OF AMENDMENTS (37 CFR § 1.192(c)(4))

Applicant filed U.S. Patent Application No. 09/591,437 on June 9, 2000. The application contained 22 total claims, 3 of which (Claims 1, 13, and 14) were independent claims. Applicants received a first Office Action, mailed February 15, 2002, wherein Claims 1-22 were rejected under 35 U.S.C. 112, 2nd paragraph and under 35 U.S.C. 102(b) as anticipated by Bos (USPN 4,900,132). Applicant filed an Amendment and Response on June 17, 2002, amending Claims 1, 2, and 13-15.

Applicant received a second Office Action, mailed October 1, 2002, rejecting Claims 1-22 under 35 U.S.C. 102(e) as anticipated by Liu et al (USPN 6,141,076). On January 2, 2003, Applicant filed an Amendment and Response to Second Office Action, arguing distinctions in the claims as compared to Liu and adding new Claims 23-26, with Claims 25 and 26 being independent.

A third and Final Office Action was mailed March 25, 2003, rejecting Claims 1-26 under 102(e) as anticipated by Liu et al (USPN 6,141,076). Applicants filed a Response to Final Office Action on May 27, 2003 requesting reconsideration in part based on the Final Office Action having

logic that Applicants were unable to follow and, to the extent it could be followed, it seemed incorrect. There was no attempt to amend any claims after the Final Office Action. An Advisory Action was mailed on June 17, 2003 stating that the application was still not in condition for allowance and repeating the same logic that could not be understood.

A Notice of Appeal was filed by Applicants on September 25, 2003 and an Appeal Brief was filed on December 1, 2003. On December 14, 2004, prosecution was re-opened and a non-final Office Action was mailed, rejecting Claim 25 under Section 112, second paragraph; Claims 1, 3-10, 14, 16-24, and 26 as unpatentable under 35 U.S.C. 103(a) over Liu (which apparently mistakenly was listed in the Office Action as USPN 4,778,259); Claims 2, 12, and 15 as being unpatentable under Section 103(a) over Liu (USPN 6,141,076) in view of Iwayama (USPN 5,323,253); objecting to Claim 11 for an antecedent basis problem but noting it was allowable if rewritten into independent form; and allowing Claim 13. An Amendment and Response was filed on March 14, 2005, amending Claim 11 and arguing distinctions in the claims as compared to Liu.

On June 3, 2005, a Final Office Action was mailed that appears to differ from the December 14, 2004 non-final Office Action only by omitting the antecedent basis objection to claim 11 and correcting the patent number for Liu to USPN 6,141,076. A Response to Final Office Action was mailed on August 3, 2005 arguing the rejection of Claim 25 and submitting evidence that the term "surface stabilized" is widely used in the ferroelectric liquid crystal art, the evidence being in the form of a published paper and a handbook on the subject, and arguing distinctions over the prior art. An Advisory Action was mailed August 24, 2005 finding the arguments to not be persuasive. A Notice of Appeal was filed, and was received by the PTO on September 7, 2005.

V. SUMMARY OF CLAIMED SUBJECT MATTER

Claim Group A: Claims 1-10, 12, and 14-24

Generally, the present invention (Claim Group A) relates to an optical device 100 (Fig. 2 and page 5, line 15 through page 6, line 34) or system 300 (Fig. 4 and page 7, line 1 through page 9, line 16) (or a method for using same) that includes a ferroelectric liquid crystal material (10). The device includes a first and second substrate (32A and 32B in Fig. 2 and 332A and 332B in Fig. 4), with alignment treatments (110A and 110B in Fig. 2 and 310A and 310B in Fig. 4) applied to surfaces of the first and second substrate. The alignment treatment on each of the two substrates induces an orientation of at least a portion of the ferroelectric liquid crystal material therebetween along an alignment direction (page 5, line 29 through page 6, line 4). The first and second substrates are located relative to each other in such a manner that the first and second alignment directions are not aligned with each other, so that a non-zero angle Ω is formed between the projections of the two alignment directions on the two substrates (page 6, lines 5-9). Further, the claimed invention requires that the device is free of chevron structures (page 6, lines 24-34).

Claim Group B: Claim 25

The invention of Claim Group B includes the features described in the first paragraph of this Section <u>plus</u> a limitation that the ferroelectric liquid crystal material is surface stabilized. (page 1, lines 5-33).

Claim Group C: Claim 26

The invention of Claim Group C includes the features described in the first paragraph of this Section <u>plus</u> a limitation that the first and second substrates are spaced apart by a distance sufficiently small to suppress formation of helixes typically formed in bulk of the ferroelectric liquid crystal material. (page 1, lines 22-25 and page 7, lines 17-25).

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

1. Claims 1, 3-10, 14, 16-24, and 26 have been rejected as unpatentable over Liu (USPN 6,141,076).

2. Claims 2, 12, and 15 have been rejected under 103(a) as being unpatentable over Liu (USPN 6,141,076) in view of Iwayama (USPN 5,323,253).

3. Claim 25 has been rejected under 35 USC 112, second paragraph, as not enabled.

VII. ARGUMENTS

Claim Group A

Claims 1, 3-10, 14, and 16-24 have been rejected as obvious over Liu. Claims 2, 12, and 15 have been rejected as obvious over the combination of Liu and Iwayama. Claim 11 is objected to as dependent on a rejected claim.

Each of the rejected claims is believed to be patentable over Liu (whether or not combined with Iwayama) at least because Liu does not disclose or suggest a cross-buffed device wherein the ferroelectric liquid crystal material is free of chevron structures. Further Liu does not discuss the ferroelectric liquid crystal material being free of chevron structures without the need to otherwise apply an additional treatment to the optical device.

Generally, conventional ferroelectric liquid crystal (FLC) devices have undesirable chevron structures that are formed in the FLC material (see discussion in applicants' patent application at page 2, lines 18-33). Various attempts have been made to prevent the formation of chevron structures, such as applying an additional treatment in the form of an electrical signal to the FLC material after it is inserted into the device (see applicants' patent application at page 2, line 34

through page 3, line 3). When the chevrons are straightened out by such an additional treatment, they are said to have a structure called "quasi-bookshelf" (see attached relevant passages (Appendix C) on pp 227-229 in Ferroelectric and Antiferroelectric Liquid Crystals, by Sven T. Lagerwall (1999) (the same passages were provided in the Response to Final Action filed May 27, 2003)).

Liu discusses chevrons and quasi-bookshelf structures in only two places in his patent (once in column 1 at lines 31-35, and again in column 4 at lines 35-37). In both places in Liu, the discussion is specifically limited to FLC cells that have either parallel or anti-parallel buffing; "cross-buffed" cells are excluded. Thus, Liu appears to be just reciting the prior-art problems with parallel-buffed devices that are also recited in applicants' patent application. Liu's teaching about his own invention, i.e. about cross-buffed FLC devices, is completely silent on the issue of chevrons. Applicants' invention is directed towards, and in its claims are limited to, FLC devices that are cross buffed (e.g., the non-zero angle Ω between the alignment directions).

It is respectfully submitted that the Examiner misrepresents what is disclosed by Liu. Liu discloses that, in a ferroelectric liquid crystal spatial light modulator, strong buffing in a 90°-twisted configuration produces a device with "relatively high scattering" (col. 4, lines 19-20). Liu again discloses (col. 4, lines 41-45) that strong buffing results in a modulator with a "multi-domain texture" having a "high transmission loss." Liu goes on to disclose, without further reference to scattering or transmission loss, that either strong or weak buffing, resulting in either strong or weak anchoring, respectively, can produce devices with "excellent contrast" or "even greater contrast" (respectively) (col. 4, lines 46-55). Liu never states or even implies that a structure created in this manner is free from chevrons. It is certainly not *inherent* that Liu's structure would be free of chevrons. "High contrast" is an undefined, relative term. All "high contrast" should be taken to mean is "contrast relatively higher than some other level of contrast." Certainly it is possible to

create a structure with relatively higher contrast than another structure without making the structure free from chevrons. The present applicant sells commercial FLC displays that are free from "scattering" and "multi-domain texture," all exhibiting "excellent contrast," all having an entirely chevron liquid crystal structure.

On the other hand, independent claims 1 and 14 claim an optical device (or, in the case of claim 14, a method for preventing formation of chevron structures in the optical device) that is free of chevron structures. Since this limitation is not found, suggested, or inherent in Liu, these claims are patentable, as are each of the claims that depend thereon. Since independent claims 1 and 14 are patentable over Liu, the dependent claims (Claims 2-12 and 15-24) are patentable as well.

<u>Claim Group B</u>

Claim 25 is patentable not only because of the limitations discussed above in conjunction with Claim Group A, but also at least because of the surface stabilized limitation in Claim 25. The Examiner has rejected Claim 25, stating that it contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. Apparently it is the limitation "wherein the ferroelectric liquid crystal material in the optical device is surface stabilized" that the Examiner feels a skilled practitioner would have difficulty with.

In fact, the term "surface stabilized" is widely used in the ferroelectric liquid crystal art. It has been used at least since 1984, as evidenced by the attached page (Appendix D) from a paper by Noel A. Clark and Sven T. Lagerwall entitled "Surface-Stabilized Ferroelectric Liquid Crystal Electro-optics: New Multistate Structures and Devices," published in Ferroelectrics vol. 59, pp. 25-67 (1984). It is also found in handbooks on the subject, as evidenced by the attached page

(Appendix E) from a chapter entitled "Electric Field Effects in Liquid Crystals," by L.M. Blinov in the *Handbook of Liquid Crystal Research* edited by Peter J. Collings and Jay S. Patel (Oxford University Press, Oxford, 1997).

From both these examples, it is clear that this term "surface stabilized" means exactly the same thing in the art as it does in applicant's specification -- an FLC device that is sufficiently thin enough to prevent helical rotation of the director of each FLC molecule through the smectic layers (patent application at Figure 1B; page 1, lines 7-25; page 5, lines 15-16; and page 7, lines 17-29).

The same terminology is widely used in U.S. patents. When searching the US patent data base, applicant finds 251 instances of patents that contain "surface stabilized" in conjunction with FLC.

We submit that the invention we claim in claim 25 is fully enabled by the drawings and language in the patent application at Figure 1B; page 1, lines 7-25; page 5, lines 15-16; and page 7, lines 17-29.

The Examiner argues in the Advisory Action mailed August 24, 2005 that he "maintains the rejection of claim 25 since the SSFLC comprising a structure free of chevron without a need to otherwise apply an additional treatment to the optical device is not conventional." Of course it is not conventional, as it is a key part of the patentable invention.

Furthermore, as evidenced by the passage in the patent application at page 1, lines 22-25, a surface stabilized ferroelectric liquid crystal can be created by suppressing the formation of helical structures in the FLC by reducing the spacing between the substrates (and thus the thickness of the FLC layer) down to a few microns. In addition, in the passages at page 7, lines 17-29, it is clear that 1 micron spherical spacers are used to maintain the substrates 332A and 332B in Figure 4 at a spacing of 1 micron before the Chisso Chemical commercial FLC mixture designated CS1025 is

inserted between the substrates. As is shown in the attached (Appendix F) data sheet from Chisso Petrochemical Corp., dated March 27, 1989, the helical pitch of CS1025 is 10 microns in the smecticC* phase. With a layer of FLC material much smaller than the helical pitch, the formation of helical structures will be eliminated and the device will be surface stabilized.

As can be appreciated, the invention of claim 25 is fully enabled by the specification, and this claim should be allowed.

Claim Group C

Claim 26 is patentable not only because of the limitations discussed above in conjunction with Claim Group A, but also at least because of the "sufficiently small spacing to suppress formation of helixes" limitation in Claim 26. This limitation is not found in Liu in an embodiment that shows cross buffing. It is only discussed with reference to conventional devices of the prior art. The Examiner points to column 3, lines 50-57 of Liu, where there is a general discussion of FLCs and suppression of helixes with thin cell thickness. There is no discussion of cross buffing relating to this discussion.

The combination of the key limitations in Claim 26 ((a) the substrates have alignment treatments with alignment directions that form a non-zero angle with each other ("cross buffing"), (b) the optical device is free of chevron structures without a need to otherwise apply an additional treatment to the optical device, and (c) the first and second substrates are spaced apart by a distance sufficiently small to suppress formation of helixes typically formed in bulk of the ferroelectric liquid crystal material) is not disclosed or suggested in Liu and thus is patentable over Liu. For this reason, in addition to the reasons discussed in conjunction with Claim Group A, the claim of Group C is patentable.

IX. CONCLUSION

Based upon the foregoing, Appellant respectfully requests the Board to reverse the Examiner's §103(a) rejections of all pending claims and to pass the above-identified patent application to issuance.

Respectfully submitted,

MARSH FISCHMANN & BREYFOGLE LLP

By: ______________________

Robert G. Crouch
Registration No. 34,806
3151 South Vaughn Way, Suite 411
Aurora, Colorado 80014
(720) 562-5506

Date: March 7, 2006

APPENDIX A

Clean Copy of the Claims

1. An optical device including a ferroelectric liquid crystal material, said optical device comprising:

a first and a second substrate;

a first alignment treatment applied to a surface of the first substrate, said first alignment treatment being intended to induce an orientation of at least a portion of said ferroelectric liquid crystal material along a first alignment direction and with a first pretilt angle α_1 with respect to a plane parallel to said first substrate;

a second alignment treatment applied to a surface of the second substrate, said second alignment treatment being intended to induce an orientation of at least another portion of said ferroelectric liquid crystal material along a second alignment direction and with a second pretilt angle α_2 with respect to a plane parallel to said second substrate; and

wherein the first substrate is located with respect to the second substrate in such a way that the surfaces of the first and second substrates onto which the first and second alignment treatments were applied, respectively, are spaced apart, generally parallel and facing each other and a projection of the first alignment direction onto the treated surface of the first substrate makes a non-zero angle Ω with respect to a projection of the second alignment direction onto the treated surface of the first substrate such that, said ferroelectric liquid crystal material being injected between the first and second substrates, the optical device is free of chevron structures without a need to otherwise apply an additional treatment to the optical device.

2. An optical device of Claim 1 wherein said ferroelectric liquid crystal material has a phase sequence of Isotropic – Nematic – Smectic A – Smectic C* – Crystalline states.

3. An optical device of Claim 1 wherein said ferroelectric liquid crystal material having a cone angle θ, said non-zero angle Ω has a predetermined value such that $\Omega \geq 2\theta$ and $\Omega \neq 180°$.

4. An optical device of Claim 1 wherein said first and second alignment treatments are specifically chosen so as to specifically induce pretilt angles of α_1 and α_2, respectively.

5. An optical device of Claim 4 wherein said first alignment treatment includes a coating of a selected alignment material, said coating being applied, cured and treated so as to specifically induce the pretilt angle of α_1.

6. An optical device of Claim 5 wherein said second alignment treatment includes a coating of another selected alignment material, said coating being applied, cured and treated so as to specifically induce the pretilt angle of α_2.

7. An optical device of Claim 4 wherein each of said pretilt angles is at most 10°.

8. An optical device of Claim 4 wherein said first and second alignment treatments are generally identical.

9. An optical device of Claim 1 wherein said first and second alignment treatments provide strong molecular anchoring of at least portions of the ferroelectric liquid crystal material located immediately adjacent to the treated surfaces of the first and second substrates.

10. An optical device of Claim 1 further comprising:

a light input directed at said optical device in such a way that the optical device in turn produces a light output of a particular optical state; and

means for electrically addressing said optical device in such a way that the particular optical state of the light output is continuously variable between a minimum optical state and a maximum optical state.

11. An optical device of Claim 10 wherein an optical retardance of the optical device remains generally constant during said continuous variation of the optical state of the light output.

12. An optical device of Claim 1 wherein said first substrate includes a reflective surface.

13. An optical system comprising:

an optical device including

a ferroelectric liquid crystal material,

a first and a second substrate,

a first alignment treatment applied to a surface of the first substrate, said first alignment treatment being intended to induce an orientation of at least a portion of said ferroelectric liquid crystal material along a first alignment direction and with a first pretilt angle α_1 with respect to a plane parallel to said first substrate,

a second alignment treatment applied to a surface of the second substrate, said second alignment treatment being intended to induce an orientation of at least another portion of said ferroelectric liquid crystal material along a second alignment direction and with a second pretilt angle α_2 with respect to a plane parallel to said second substrate, and

wherein the first substrate is located with respect to the second substrate in such a way that the surfaces of the first and second substrates onto which the first and second alignment treatments were applied, respectively, are spaced apart, generally parallel and facing each other and a projection of the first alignment direction onto the treated surface of the first substrate makes a non-zero angle Ω with respect to a projection of the second alignment direction onto the treated surface of the first substrate such that, said ferroelectric liquid crystal material being injected between the

first and second substrates, the optical device is free of chevron structures without a need to otherwise apply an additional treatment to the optical device;

a light input directed at said optical device in such a way that the optical device in turn produces a light output of a particular optical state; and

means for electrically addressing said optical device in such a way that the particular optical state of the light output is continuously variable between a minimum optical state and a maximum optical state wherein an optical retardance of the optical device remains generally constant during said continuous variation of the optical state of the light output.

14. In an optical device including a ferroelectric liquid crystal material, a method for preventing formation of chevron structures in the optical device, said method comprising the steps of:

providing a first and a second substrate;

applying a first alignment treatment to a surface of the first substrate, said first alignment treatment being intended to induce an orientation of at least a portion of said ferroelectric liquid crystal material along a first alignment direction and with a first pretilt angle α_1 with respect to a plane parallel to said first substrate;

applying a second alignment treatment to a surface of the second substrate, said second alignment treatment being intended to induce an orientation of at least another portion of said ferroelectric liquid crystal material along a second alignment direction and with a second pretilt angle α_2 with respect to a plane parallel to said second substrate;

locating the first substrate with respect to the second substrate in such a way that the surfaces of the first and second substrates onto which the first and second alignment treatments were applied, respectively, are spaced apart, generally parallel and facing each other and a

projection of the first alignment direction onto the treated surface of the first substrate makes a non-zero angle Ω with respect to a projection of the second alignment direction onto the treated surface of the first substrate; and

injecting the ferroelectric liquid crystal material between the first and second substrates such that the optical device is free of chevron structures without a need to otherwise apply an additional treatment to the optical device.

15. The method of Claim 14 further comprising the step of selecting a ferroelectric liquid crystal material having a phase sequence of Isotropic – Nematic – Smectic A –Smectic C* – Crystalline states.

16. The method of Claim 14 wherein, said ferroelectric liquid crystal material having a cone angle θ, said step of securing the first substrate with respect to the second substrate includes the step of specifying the value of angle Ω to have a value such that $\Omega \geq 2\theta$ and $\Omega \neq 180°$.

17. The method of Claim 14 further comprising the step of choosing said first and second alignment treatments so as to specifically induce pretilt angles of α_1 and α_2, respectively.

18. The method of Claim 17 wherein said step of applying the first alignment treatment to a surface of the first substrate further includes the steps of:

coating the surface with a selected alignment material;

curing said coated surface using a heating and cooling sequence; and

rubbing said cured, coated surface using a buffing material in such a way that at least a portion of said ferroelectric liquid crystal material tends to become orientated of along the first alignment direction with the first pretilt angle α_1 with respect to the plane parallel to said first substrate.

19. The method of Claim 18 said step of applying the second alignment treatment to a surface of the second substrate further includes the steps of:

coating the surface with another selected alignment material;

curing said coated surface using another heating and cooling sequence; and

rubbing said cured, coated surface using a buffing material in such a way that at least another portion of said ferroelectric liquid crystal material tends to become orientated of along the second alignment direction with the second pretilt angle α_2 with respect to the plane parallel to said second substrate.

20. The method of Claim 17 wherein sad step of applying the first alignment treatment to a surface of the first substrate and said step of applying the second alignment treatment to a surface of the second substrate are generally identical.

21. The method of Claim 17 wherein said choosing step further includes the step of taking into consideration molecular anchoring properties of said first and second alignment treatments so as to choose first and second alignment treatments to specifically induce pretilt angles of α_1 and α_2, respectively, while providing strong molecular anchoring of at least portions of the ferroelectric liquid crystal material located immediately adjacent to the treated surfaces of the first and second substrates.

22. The method of Claim 14 further comprising the steps of:

providing a light input to said optical device in such a way that the optical device in turn produces a light output of a particular optical state; and

electrically addressing said optical device in such a way that the particular optical state of the light output is continuously variable between a minimum optical state and a maximum optical state.

23. An optical device of Claim 9, wherein the first and second pretilt angles are non-zero.

24. An optical device of Claim 21, wherein the first and second pretilt angles are non-zero.

25. An optical device including a ferroelectric liquid crystal material, said optical device comprising:

a first and a second substrate;

a first alignment treatment applied to a surface of the first substrate, said first alignment treatment being intended to induce an orientation of at least a portion of said ferroelectric liquid crystal material along a first alignment direction and with a first pretilt angle α_1 with respect to a plane parallel to said first substrate;

a second alignment treatment applied to a surface of the second substrate, said second alignment treatment being intended to induce an orientation of at least another portion of said ferroelectric liquid crystal material along a second alignment direction and with a second pretilt angle α_2 with respect to a plane parallel to said second substrate; and

wherein the first substrate is located with respect to the second substrate in such a way that the surfaces of the first and second substrates onto which the first and second alignment treatments were applied, respectively, are spaced apart, generally parallel and facing each other and a projection of the first alignment direction onto the treated surface of the first substrate makes a non-zero angle Ω with respect to a projection of the second alignment direction onto the treated surface of the first substrate such that, said ferroelectric liquid crystal material being injected between the first and second substrates, the optical device is free of chevron structures without a need to otherwise apply an additional treatment to the optical device; and

wherein the ferroelectric liquid crystal material in the optical device is surface stabilized.

26. An optical device including a ferroelectric liquid crystal material, said optical device comprising:

a first and a second substrate;

a first alignment treatment applied to a surface of the first substrate, said first alignment treatment being intended to induce an orientation of at least a portion of said ferroelectric liquid crystal material along a first alignment direction and with a first pretilt angle α_1 with respect to a plane parallel to said first substrate;

a second alignment treatment applied to a surface of the second substrate, said second alignment treatment being intended to induce an orientation of at least another portion of said ferroelectric liquid crystal material along a second alignment direction and with a second pretilt angle α_2 with respect to a plane parallel to said second substrate; and

wherein the first substrate is located with respect to the second substrate in such a way that the surfaces of the first and second substrates onto which the first and second alignment treatments were applied, respectively, are spaced apart, generally parallel and facing each other and a projection of the first alignment direction onto the treated surface of the first substrate makes a non-zero angle Ω with respect to a projection of the second alignment direction onto the treated surface of the first substrate such that, said ferroelectric liquid crystal material being injected between the first and second substrates, the optical device is free of chevron structures without a need to otherwise apply an additional treatment to the optical device; and

wherein the first and second substrates are spaced apart by a distance sufficiently small to suppress formation of helixes typically formed in bulk of the ferroelectric liquid crystal material.

APPENDIX B

Copy of U.S. Patent No. 6,141,076.

APPENDIX C

A copy of passages from Ferroelectric and Antiferroelectric Liquid Crystals, by Sven T. Lagerwall (1999).

Sven T. Lagerwall

Ferroelectric and Antiferroelectric Liquid Crystals

WILEY-VCH

Weinheim · New York · Chichester
Brisbane · Singapore · Toronto

Prof. Sven T. Lagerwall
Physics Department
Chalmers University of Technology
S-412 96 Göteborg
Sweden

Cover picture:
Zigzag defects in a smectic C*.
Courtesy of Noel Clark and Tom Rieker.

Library of Congress Card No. applied for

A catalogue record for this book is available from the British Library

Deutsche Bibliothek Cataloguing-in-Publication Data:
Lagerwall, Sven T.:
Ferroelectric and antiferroelectric liquid crystals / Sven T. Lagerwall. – Weinheim ; New York ; Chichester ; Brisbane ; Singapore ; Toronto : Wiley-VCH, 1999
ISBN 3-527-29831-2

Composition and Printing: Konrad Triltsch, Druck- und Verlagsanstalt GmbH, D-97070 Würzburg.
Bookbinding: J. Schäffer GmbH & Co. KG, D-67269 Grünstadt
Printed in the Federal Republic of Germany.

way between 1 and 2), which gives a contribution to the threshold for the process. Generally speaking, the bulk switching on either side of the chevron interface preceeds the switching in the interface. The latter contributes to the latching and thus to the bistability.

As seen from Fig. 96b, the switching process is unambiguous as regards the motion of $\boldsymbol{n}$ and $\boldsymbol{P}$ (sterically bound to $\boldsymbol{n}$): on the upper side of the chevron, $\boldsymbol{P}$ rotates counterclockwise, on the lower side it rotates clockwise when we switch from 1 to 2; everything turns around in the reverse switching direction. This explains why there are no twist and antitwist domains like the ones observed in twisted nematics prior to the time when chiral dopants were added in order to promote a certain twist sense.

So far we have described the switching concentrating on the chevron interface, completely disregarding what could happen at the two bounding (electrode) surfaces. In fact, if the anchoring condition on the surfaces is very strong, switching between up and down states of polarization will only take place at the chevron interface. At high voltage this will more or less simultaneously take place in the whole sample. At low voltage it will be possible to observe the appearance of down domains as "holes" created in an up background, or vice versa, in the shape of so-called boat domains (see Fig. 105) in the chevron interface (easily localized to this plane by optical microscopy). The walls between up and down domains have the configuration of strength one (or 2π) disclinations in the $\boldsymbol{P}$ field.

It should be pointed out that the uniqueness of director rotation during the switching process is not a feature related to the chevron per se, but only to the fact that the chevron creates a certain $\boldsymbol{P}$-tilt at the chevron interface. If the boundary conditions of the glass surfaces involved a similar $\boldsymbol{P}$-tilt, this will have the same effect.

A glance at Fig. 97 reveals another important consequence of the chevron structure. As $\boldsymbol{P}$ is not along $\boldsymbol{E}$ (applied field) there will always be a torque $\boldsymbol{P}\times\boldsymbol{E}$ tending to straighten up the chevron to an almost upright direction. Especially in antiferroelectric liquid crystals, which are used with very high P values, this torque is sufficiently strong for almost any applied field, for instance normal addressing pulses, to raise and keep the structure in a so-called quasi-bookshelf structure (QBS) under driving conditions. In ferroelectric liquid crystals, presently with considerably lower P values, the same effect was previously employed to ameliorate contrast and

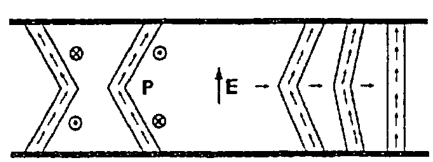


Figure 97. The fact that even after switching the polarization $\boldsymbol{P}$ is not entirely in the direction of the applied field will tend to raise the chevron structure into a more upright position, so decreasing the effective δ but breaking up the layers in a perpendicular direction. This gives a characteristic striped texture from the newly created, locked-in defect network.

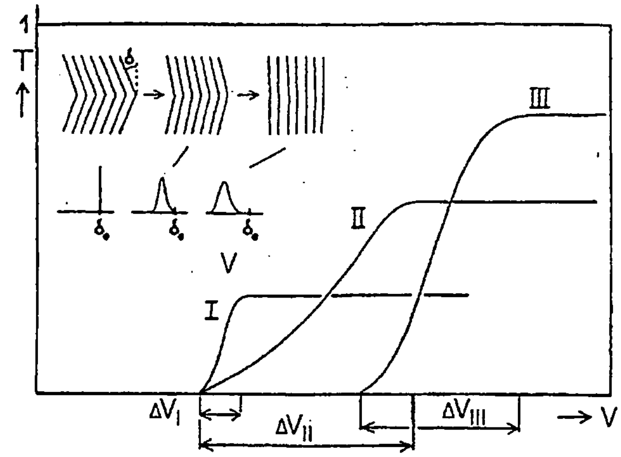
threshold properties, by conditioning the chevron FLC to QBS FLC by the application of AC fields [169]. The effect on the switching threshold can be extracted from Fig. 96. When the chevron structure is straightened up, δ decreases and the two cones overlap more and more, leading to an increasing distance between 1 and 2, as well as further compression of the tilt angle θ in order to go between 1 and 2. The threshold thus increases, in agreement with the findings of the Philips (Eindhoven) group. On the other hand, this straightening up to QBS violates the conservation of smectic layer thickness d_C, which will lead to a breaking up of the layers in a direction perpendicular to the initial chevrons, thus causing a buckling out of the direction running perpendicular to the paper plane of Fig. 97.

8.4 Analog Grey Levels

As we just pointed out, in the chevron structure the polarization is no longer collinear with the external field. This can be used (for materials with a high value of P) to straighten up the chevron into a so-called quasi-bookshelf structure, combining some of the advantages from both types of structure. For instance, it can combine a high contrast with a continuous gray scale.

How to produce analog gray levels in an SSFLC display is perhaps not so evident, because the electrooptic effect which we have essentially dealt with so far offers two optical states, hence it is digital. Nevertheless, the shape of the hysteresis curve reveals that there must be small domains with a slightly varying threshold, in some analogy with the common ferromagnetic case. Normally, however, the flank of the curve is not sufficiently smeared out to be controlled and to accommodate more than a few levels. Curve I of Fig. 98 shows the transmission–voltage characteristics for a typical SSFLC cell with the layers in the chevron configuration [165]. The threshold voltage is fairly low, as well as the achievable transmission in the bright state, leading to a low brightness–contrast ratio. The position and sharpness of the threshold curve reflect the relatively large and constant chevron angle δ_0 in the sample. If a low frequency AC voltage of low amplitude (6 – 10 V) is applied, the smectic layers will be straightened up towards the vertical due to the $P-E$ coupling, so that the local polarization vector increases its component along the direction of the field. This field action, which requires a sufficiently high value of P, breaks the layer ordering in the plane of the sample and introduces new defect structures, which are seen invading the sample. The result is that the chevron angle δ is reduced, on average, and the threshold smeared out, as shown by curve II. Lower δ means a larger switching angle (and higher threshold), and thus higher transmission. Still higher transmission can be achieved by an additional treatment at a somewhat higher voltage (±25 V), giving threshold curve III, corresponding to a new distribution around a lower δ-value and a microdomain texture on an even finer scale.

Figure 98. Amplitude-controlled gray scale in SSFLC. The chevron structure is transformed to a quasi-bookshelf (QBS) structure by external field treatment. In addition to giving gray shades, the QBS structure increases the brightness and the viewing angle. This method of producing gray levels was developed by the Philips (Eindhoven) group, who called it the "texture method".



The actual switching threshold is a complicated quantity, not fully understood (no successful calculation has been presented so far), and usually expressed as a voltage–time area threshold for the switching pulse. For a given pulse length it is, however, reasonable that the amplitude threshold increases according to Fig. 98 when the average value of δ decreases. There are at least two reasons for this, as illustrated by Fig. 96. First, it is seen that the distance between the two positions n_1 and n_2 in the chevron kink level (which acts as a third, internal surface), as well as the corresponding positions at the outer surfaces and in between, increase when δ decreases. It would therefore take a longer time to reach and pass the middle transitory state, after which the molecules would latch in their new position. In addition, it is seen that the local deformation of the cone i.e., a decrease of the tilt angle θ, which is necessary to actuate the transition from n_1 to n_2, increases when δ decreases. (A paradox feature of this deformation model is that it works as long as $\delta \neq 0$, whereas $\delta = 0$ gives no deformation at all – but also no chevron – at the chevron kink level.)

The smectic layer organization corresponding to curves II and III of Fig. 98 is generally characterized as a quasi-bookshelf (QBS) structure, denoting that the layers are essentially upright with only a small chevron angle. The QBS structure has a very large gray scale capacity. This might, however, possibly not be utilized to advantage in a passively driven display (as it can in the AFLC version). Its drawback in this respect is that the shape of the threshold curve is temperature-dependent, which leads to the requirement of a very well-controlled and constant temperature over the whole area of a large display. Furthermore, the QBS structure is a metastable state. Finally, the microdomain control of gray shades requires an additional sophistication in the electronic addressing: in order to achieve the same transmission level for a given applied amplitude, the inherent memory in the microdomains has to be deleted, which is done by a special blanking pulse. Using this pulse, the display is reset to the same starting condition before the writing pulse arrives. As a result of these features, it is not clear whether the microdomain method will be successfully applied

APPENDIX D

A paper by Noel A. Clark and Sven T. Lagerwall entitled "Surface-Stabilized Ferroelectric Liquid Crystal Electro-optics: New Multistate Structures and Devices," published in Ferroelectrics vol. 59, pp. 25-67 (1984).

Ferroelectrics, 1984, Vol. 59, pp. 25–67
0015-0193/84/5901-0025/$18.50/0

SURFACE-STABILIZED FERROELECTRIC LIQUID CRYSTAL ELECTRO-OPTICS: NEW MULTISTATE STRUCTURES AND DEVICES

NOEL A. CLARK

Condensed Matter Laboratory, Department of Physics, University of Colorado, Boulder, Colorado 80309

and

SVEN T. LAGERWALL

Department of Physics, Chalmers University of Technology, S-41296 Goteborg, Sweden

(*Received March 13, 1984*)

TABLE OF CONTENTS

We describe a variety of new electro-optic effects and devices which can be made using the surface-stabilized-ferroelectric-liquid-crystal (SSFLC) geometry. These devices are made possible by application of surface interactions and bulk liquid crystal conditions, recently discovered in SSFLCs, including non-planar boundary conditions, POLAR boundary conditions, boundaries with multiple physical states, intrinsic spontaneous polarization splay, and layers tilted relative to the bounding plates. Using these alone or in combination produces an extensive collection of possible SSFLC structures with monostable, bistable, or multistable states. Such DEVICE STRUCTURES are categorized by a scheme based on structural symmetry and the specific conditions used. Particular device applications of structures employing two, three, and four state devices to nonemissive displays, color displays, and light valves are discussed.

I. INTRODUCTION

A. Previous Work

In earlier papers[1,2] we have described a liquid crystal electro-optic device employing tilted chiral smectic ferroelectric liquid crystals (FLCs). In that device the liquid crystal is disposed between parallel plates with the planar smectic layers normal to their surface. The plates are treated so that the molecules near the plate surface would adopt an orientation having the average molecular long axis direction parallel to the surface plane. That is, the molecular director, $\hat{n}$, is constrained at the surface to lie in the surface plane. This condition, when combined with the additional constraint that the director make the angle, Ψ_0, with the normal to the layers, leads to a geometry in which, if the plates are sufficiently close together, the intrinsic helical configuration of $\hat{n}$ which is present in the bulk will be suppressed, leaving two surface stabilized states of the molecular orientation configuration, each having the ferroelectric polarization normal to the plates but in opposite directions (see Figure 1, Reference 1, 2, or 5 for this geometry). We will refer to devices such as this, which employ surface interactions to stably unwind the spontaneous ferroelectric helix, as surface- stabilized-ferroelectric-liquid-crystal (SSFLC) devices.

The original SSFLC device exhibits several novel features which make it attractive in electro-optic applications and which distinguish it from other liquid crystal devices: (1) Optic axis rotation about the sample normal—A ferroelectric smectic in this geometry behaves optically as a biaxial slab with the optic axes nearly along the director orientation. The biaxiality is generally weak, so the behavior is essentially uniaxial with the uniaxis along the director. The effect of switching is to rotate the uniaxis about the normal to the surface through an angle of twice the tilt angle Ψ_0. This is the only liquid crystal parallel-plate geometry allowing a rotation of the uniaxis of a homogeneous sample about the surface normal. (2) *Strong–weak*

APPENDIX E

A page from a chapter entitled "Electric Field Effects in Liquid Crystals," by L.M. Blinov in the *Handbook of Liquid Crystal Research* edited by Peter J. Collings and Jay S. Patel (Oxford University Press, Oxford, 1997).

Handbook of Liquid Crystal Research

PETER J. COLLINGS and JAY S. PATEL
Editors in Chief

OXFORD UNIVERSITY PRESS
New York Oxford
1997

To Diane and Susan

OXFORD UNIVERSITY PRESS

Oxford New York
Athens Auckland Bangkok Bogotá
Bombay Buenos Aires Calcutta Cape Town
Dar es Salaam Delhi Florence Hong Kong Istanbul
Karachi Kuala Lumpur Madras Madrid Melbourne
Mexico City Nairobi Paris Singapore
Taipei Tokyo Toronto

and associated companies in
Berlin Ibadan

Published by Oxford University Press, Inc.,
198 Madison Avenue, New York, New York 10016

Oxford is a registered trademark of Oxford University Press

Library of Congress Cataloging-in-Publication Data

Handbook of Liquid Crystal Research / Peter J. Collings and
Jay S. Patel, editors in chief.
p. cm.
Includes bibliographical references and index.
ISBN 0-19-508442-X
(hardcover : alk. paper)
1. Liquid Crystals. I. Collings, Peter J., 1947- .
II. Patel, Jay S.
QD923.H36 1997
530.4'29—dc20 96-31118 CIP

Printing (last digit): 9 8 7 6 5 4 3 2 1

Printed in the United States of America
on acid-free paper

CONTENTS

coercivity loop ΔV in the voltage dependence of the polarization

$$W_d = (1/8)\Delta V P_S \qquad (5.102)$$

and (ii) by measuring the free relaxation times τ_d to the bistable states for the FLC director:

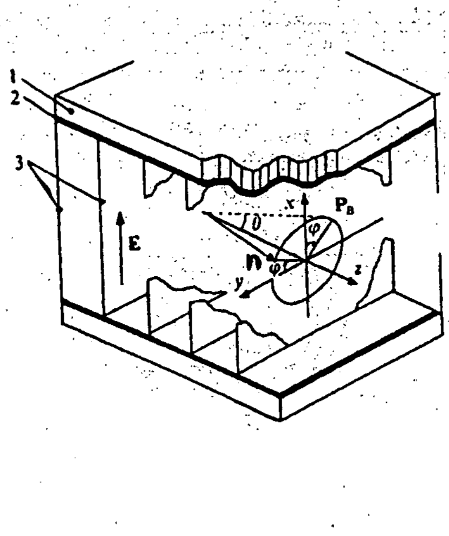
$$W_d = \gamma_\varphi d/4\tau_d \qquad (5.103)$$

where γ_φ is the viscosity for the φ relaxation of the director.

5.5.2.2 The Clark–Lagerwall Effect

Let us consider the best known electrooptical phenomenon in FLCs, the Clark–Lagerwall effect, which results in the director reorientation from one bistable state to another, when the external electric field changes its sign [12] (FIGURE 5.39). In this case, smectic layers are perpendicular to the substrates and the director moves along the surface of a cone, whose axis is normal to the layers and parallel to the cell substrates. In each final position of its deviation, the director remains parallel to the substrates, thus transforming a cell into a uniaxial phase plate. The origin of switching the director is an interaction of the polarization **P** perpendicular to the director with the electric field **E**. The maximum variation of the transmitted intensity is achieved when an FLC cell is placed between crossed polarizers, so that an axis of the input polarizer coincides with one of the final director positions. The total angle of switching equals twice the

FIGURE 5.39. An FLC cell with the smectic layers (3) perpendicular to the substrates (1) and current conducting layers (2). **E** – electric field, **n** – director.



tilt angle θ. The Clark–Lagerwall effect is observed in the so-called surface stabilized FLC structures (SSFLC) [12,226,227]. In SSFLC cells, $d \ll h$ and the helix is unwound by the walls.

The variation of the azimuthal director angle φ in the Clark–Lagerwall effect is described by the equation for the torque equilibrium, which follows from minimization of the free energy (5.101):

$$\gamma_\varphi \frac{\partial \varphi}{\partial t} + K\frac{\partial^2 \varphi}{\partial x^2} = P_S E \sin\varphi + \frac{\Delta\varepsilon E^2}{4\pi}\sin\varphi\cos\varphi \qquad (5.104)$$

assuming the FLC to be uniaxial, $\Delta\varepsilon = (\varepsilon_\parallel - \varepsilon_\perp)\sin^2\theta$, and K is a combination of K_1, K_2, and K_3 from (5.97). When the helix is unwound by the cell walls, the second term in the left part vanishes.

The boundary conditions are:

$$K\frac{\partial\varphi}{\partial x} + W_p \sin\varphi \pm W_d \sin 2\varphi|_{x=d,0}. \qquad (5.105)$$

For polarizations $P_S > 10\,\mathrm{nC\,cm^{-2}}$, driving fields $E < 10\,\mathrm{V\,\mu m^{-1}}$ and dielectric anisotropy $|\Delta\varepsilon| < 1$, we have

$$|\Delta\varepsilon E/4\pi| \ll P \qquad (5.106)$$

and, consequently, the second term in the right-hand part of (5.104) may be omitted. In this case the response times in the Clark–Lagerwall effect are given by

$$\tau_\varphi = \gamma_\varphi / P_S E. \qquad (5.107)$$

If inequality (5.106) is invalid, which occurs for sufficiently high fields, $|\Delta\varepsilon E/4\pi| \simeq P_S$, the response times of the Clark–Lagerwall effect sharply increase for positive $\Delta\varepsilon$ values. In contrast, for negative values of $\Delta\varepsilon$, the corresponding switching times become shorter [228,229]. This is especially important for practical applications because it promotes an increase in the information capacity of FLC displays. For $|\Delta\varepsilon E/4\pi| \gg P_S$, the FLC switching times τ are approximately governed by the field squared, $\tau \simeq 4\pi\gamma_\varphi/\Delta\varepsilon E^2$, as in the Frederiks effect in nematics.

Reference [230] shows that two regimes of switching exist in the Clark–Lagerwall effect, separated by threshold field E_{th}:

$$E_{th} \cong 4W_d/P_S d. \qquad (5.108)$$

For $E < E_{th}$, one observes the motion of domain walls, separating the regions of differently oriented polarization **P** and −**P**. The switching time is defined by the motion of the walls. If $E > E_{th}$ (the Clark–

APPENDIX F

Data sheet from Chisso Petrochemical Corp., dated March 27, 1989.

CHISSO PETROCHEMICAL CORP.
RESEARCH CENTER
ICHIHARA JAPAN

No. 1

CHIRAL SMECTIC MIXTURES

Mar. 27, 1989

MIXTURE:	CS-	1011	1013	1014	1015	1016	1017	1022	1023	1024	1025	1026
TRANSITION TEMPERATURES/°C												
Cr ----→ SmC*		UK[1]	UK	-21	-17	-21	-20	-11	-4	-12	-3	-7
SmC* ----→ SmA		56	63	54	57	56	55	60	68	62	64	64
SmA ----→ N*		78	70	69	68	68	64	72	78	82	84	82
N* ----→ Iso		91	80	81	78	73	68	85	93	90	94	92
SPONTANEOUS POLARIZATION[2] /$nCcm^{-2}$	(25°C)	-13.0	-15.0	-5.4	-6.6	-9.0	-9.3	-34.7	-13.4	-46.9	-16.4	-26.0
TILT ANGLE /deg	(25°C)	22	26	22	26	25	26	25	26	25	21	22
PITCH /μm	N* PHASE ($\sim T_N$[3])	+32	-)50	-)50	+12	+1	+27	+14	+16	+)50	+9	+19
	SmC* PHASE (25°C)	-5	-6	-5	-3	-2	-1	14	-4	)20	10	10
RESPONSE TIME /μsec	(40°C)	382	332	195	126	116	113	48	98	46	52	49
	(25°C)	1054	884	329	219	192	185	94	151	73	73	64
E=5V/μm	(0°C)	—	18000	3000	—	1460	2540	688	742	518	450	382
REMARKS		1) UNKNOWN 2) MEASURED WITH THE TRIANGLE SHAPED VOLTAGE METHOD 3) N*→SmA TRANSITION TEMPERATURE										